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(54) **Portable heartrate monitor**

(57) A portable electronic device, such as a wristwatch, incorporates a photoelectric heartbeat sensor (34) which illuminates part of the user's blood vessels (48) and detects changes in the amount of light reflected. High sensitivity is attained by incorporation of a lens (50) to direct and focus the illuminating and reflected light travelling from a source 36 and back to a detector 20, with loss of light by dispersion being substantially eliminated. The detector may be in the form of a ring surrounding the source.

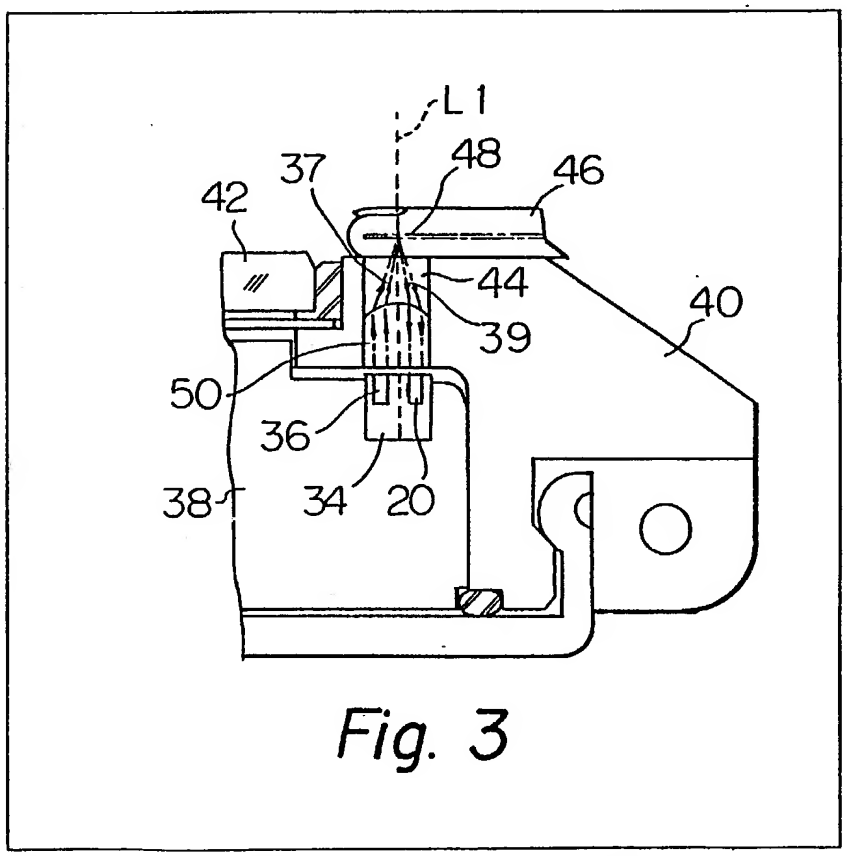

Fig. 3

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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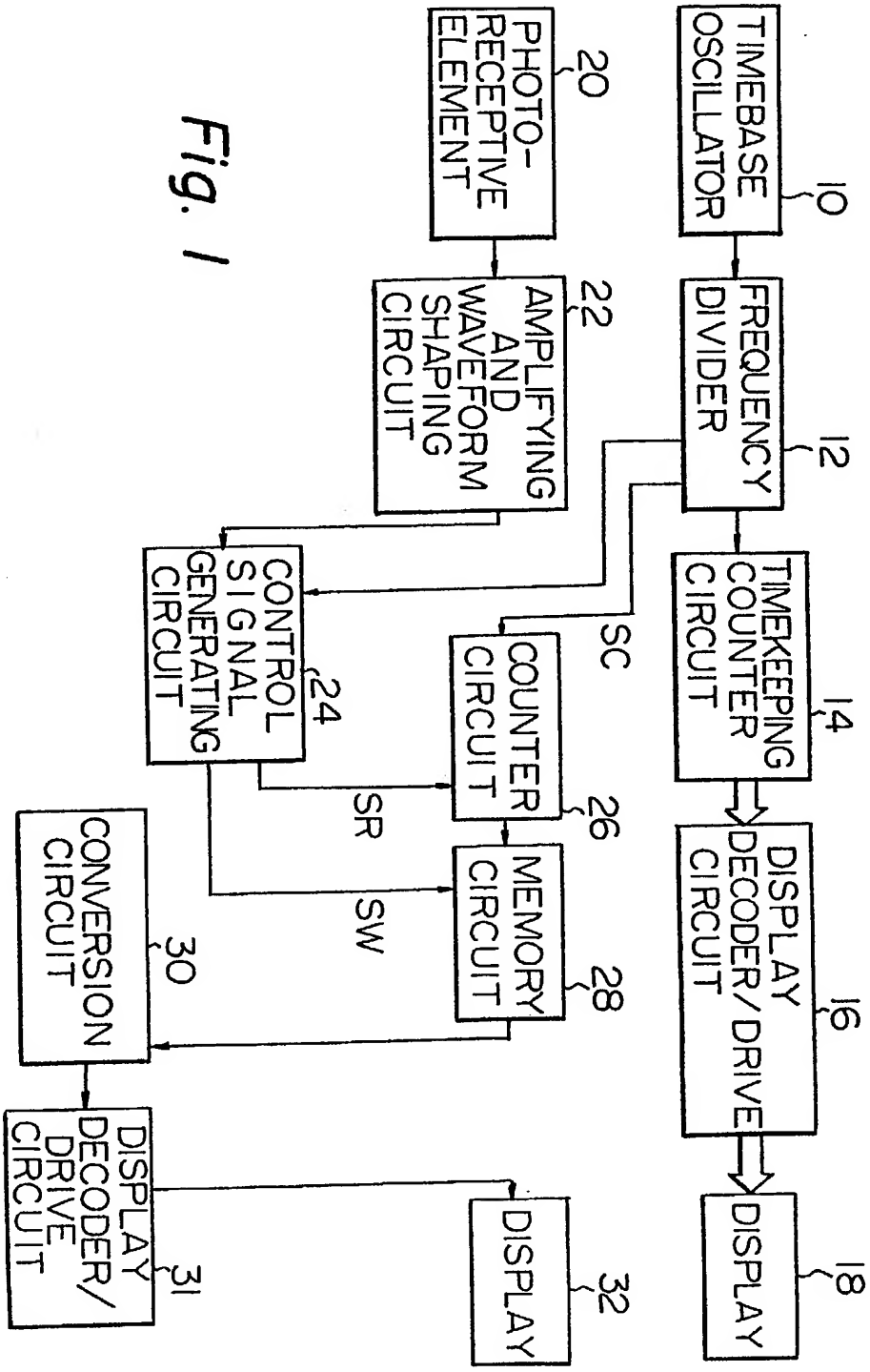

Fig. 1

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Fig. 2

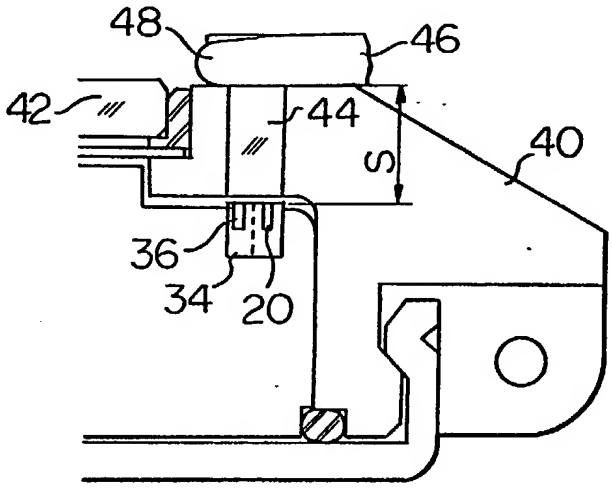
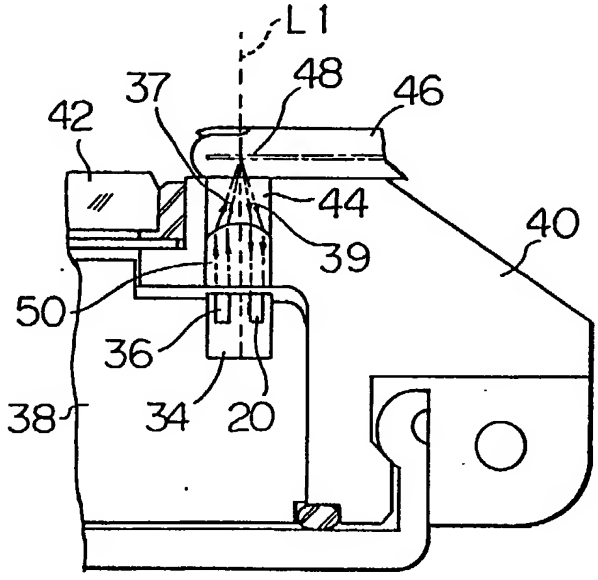


Fig. 3



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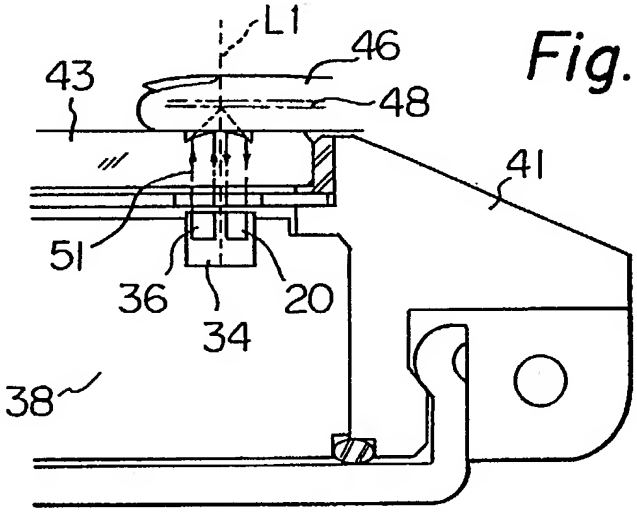


Fig. 4

Fig. 6

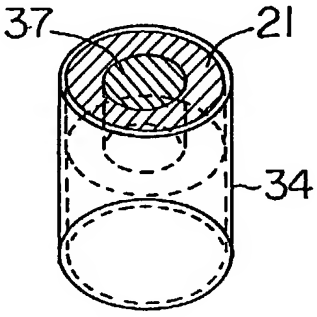
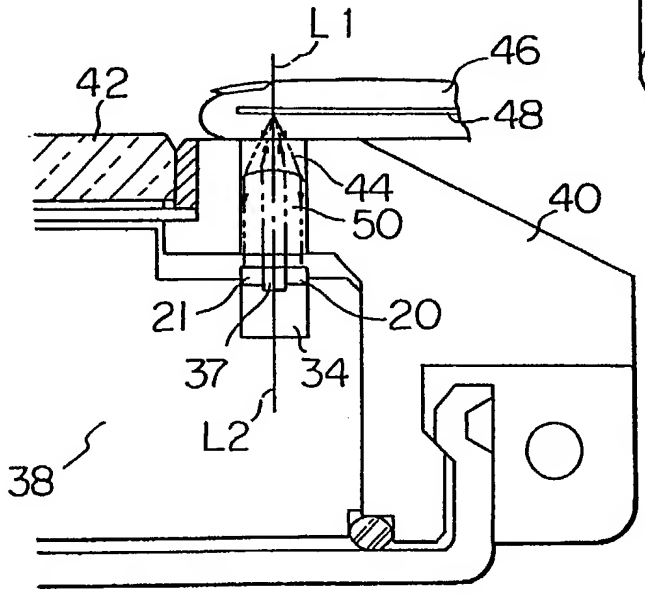


Fig. 5



SPECIFICATION

Portable electronic device

The present invention relates to a portable electronic device, such as a wristwatch, which is equipped with a heartbeat monitor function whereby the user of the device can perform personal heartbeat rate measurement in a rapid and automatic manner, with the results of the heartbeat rate measurement being displayed in digital form.

Various systems have been proposed in the prior art for performing heartbeat rate measurement utilizing some form of transducer for generating electrical signals in response to the various changes which periodically occur in the body due to the heartbeat. In particular, systems have been proposed in which some form of electro-optical sensor is utilized to detect changes in an amount of reflected or transmitted light which result from the heartbeat action upon the blood vessels. Generally, in prior art systems of this type, light emitted by a suitable source is generated within an aperture, with a part of the user's body such as a finger or wrist being placed against an open end of the aperture, and with some form of photo-electric sensor being provided within the cavity to receive light reflected back from the user's body. This light will vary periodically in response to periodic changes occurring in the blood vessels as a result of the heartbeat, so that a signal is produced from the photo-electric sensor which varies periodically in accordance with the heartbeat. Suitable processing can then be applied to this signal whereby the heartbeat can be displayed in analog or digital form.

Such prior art devices have a basic disadvantage in that the detection sensitivity of the photo-electric sensor is very low, due to dispersion of the light over the path between the light-emitting element and the user's skin surface, and within the user's body before the light actually reaches a blood vessel and is reflected therefrom. Thus, it is necessary for the body part being subjected to monitoring (e.g. a finger or wrist) to be pressed into very close contact with the cavity from which the light is emitted. Even if this is done, various problems may still arise due to the high degree of loss of light from dispersion and the resultant very low level of detection sensitivity.

There is therefore a requirement for a heartbeat monitor system for use in a portable electronic device which will overcome the disadvantage of the prior art described above, by providing enhanced detection sensitivity. This requirement is satisfied by the present invention, as described hereinafter, by utilizing an optical lens to direct and focus light used to sense the heartbeat through changes in the blood vessels resulting therefrom.

According to the present invention, there is provided a portable electronic device provided with a heartbeat rate measurement system, comprising: an outer case for containing said portable electronic device; optical lens means mounted in said case for transferring light between the exterior and interior of said case; a heartbeat sensor disposed inward of said optical lens means, said heartbeat sensor comprising a photo-emissive element and a photo-receptive element, said photo-emissive element being positioned with respect to said optical lens means such as to transmit light emitted therefrom through said optical lens means to the exterior of said case, said optical lens means acting to focus said emitted light at a focal point external to said case, and said photo-receptive element being positioned with respect to said optical lens means such as to receive said emitted light after reflection thereof from a portion of human body positioned external to said case, said optical lens means acting to direct and concentrate said reflected light on to said photo-receptive element, said photo-receptive element being responsive to variations in the level of said reflected light corresponding to a heartbeat of said human body for producing a heartbeat signal; heartbeat signal processing circuit means for operating on said heartbeat signal to produce output signals indicative of the repetition rate of said heartbeat; and display means responsive to said output signals from said heartbeat signal processing circuit means for displaying said heartbeat rate.

Embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which;

Fig. 1 is a simplified block circuit diagram illustrating the configuration of an embodiment of an electronic wristwatch which incorporates a heartbeat rate measurement system according to the present invention;

Fig. 2 is a partial cross-sectional diagram showing a prior art arrangement for a heartbeat sensor;

Fig. 3 is a partial cross-sectional diagram of an electronic wristwatch which incorporates a heartbeat rate measurement system according to the present invention, showing the arrangement of a heartbeat sensor;

Fig. 4 is a partial cross-sectional diagram of an electronic wristwatch showing another embodiment of an heartbeat sensor according to the present invention;

Fig. 5 is a partial cross-sectional diagram of an electronic wristwatch showing another embodiment of an heartbeat sensor according to the present invention, in which a photo-receptive element and photo-emissive element are disposed concentrically;

Fig. 6 is an oblique view illustrating the configuration of the photo-emissive element and photo-receptive element in the heartbeat sensor embodiment of Fig. 5.

Fig. 1 is a simplified block circuit diagram of an embodiment of an electronic wristwatch provided with a heartbeat measurement system according to the present invention. Numeral 10 denotes a time base oscillator circuit, which generates a

standard frequency timebase signal which is input to a frequency divider circuit 12, comprising a number of frequency divider stages. A unit time signal is output from frequency divider circuit 12 and input to a timekeeping counter circuit 14, which performs counting thereof to produce timekeeping signals corresponding to the minutes, hours, etc of time. These signals are applied to a display decoder-driver circuit 16, which responds by producing drive signals for driving segments of a digital display device 18, for thereby displaying time information in digital form.

Numeral 20 denotes a photo-receptive element, and numeral 22 an amplifying and waveform shaping circuit. Light reflected from a portion of the human body, by illumination means described hereinafter, is modulated in amplitude by movements of the blood vessels resulting from the heartbeat, and a signal is therebey output from photo-receptive element 20 which varies in amplitude in accordance with the heartbeat. This signal is input to an amplifying and waveform shaping circuit 22, which performs signal processing thereof to produce a single pulse for each heartbeat. These pulses are applied to a control signal generating circuit 24, which generates a single pulse of a write signal SW in response to each heartbeat pulse, a single pulse of a reset signal SR which is slightly delayed with respect to the SW pulse. These pulses are produced through processing which employs signals from an intermediate stage of frequency divider circuit 12. Numeral 26 denotes a counter circuit coupled to count pulses of a clock signal SC produced from an intermediate stage of frequency divider circuit 12, having a suitable predetermined frequency, and which is also coupled to receive the reset signal SR. Numeral 28 denotes a memory circuit 28, which is coupled to receive output signals from counter circuit 26 and also the write signal SW. Each time a heartbeat pulse is output from circuit 22, an SW signal pulse is input to memory circuit 28, causing the count contents of counter circuit 26 to be stored in memory circuit 28. Immediately thereafter, the count in counter circuit 26 is reset to zero, and the counter begins counting pulses of clock signal SC from frequency divider circuit 12. This counting continues until the next heartbeat pulse is input to control signals generating circuit 24, whereupon a new count value is written into memory circuit 28. It will thus be apparent that since the frequency of clock signal SC is fixed, the count value stored in memory circuit 28 will be proportional to the period of the heartbeat which is being measured. Numeral 30 denotes a conversion circuit, which performs digital processing of the contents of memory circuit 28 to produce data signals representing the heartbeat rate as a frequency, e.g. in the form of a number of beats per minute. These data signals are input to a display drive/decoder circuit 31, which thereby produces drive signals which are applied to a display device 32 to provide a digital display of the heartbeat rate.

Various means are known in the art for implementing the circuit blocks described above, using digital techniques, and therefore not detailed description thereof will be given. The memory circuit 28, for example, can comprise a presettable counter circuit, with write signal SW being a counter preset signal. In addition, various other methods of processing the signals produced by photo-receptive element 20 may be envisaged, or modifications to the arrangement shown may be performed. For example, a frequency divider circuit can be provided to perform frequency division of the output signal from amplifying and waveform shaping circuit 22 and the output signal from the latter frequency divider circuit applied to control signal generating circuit 24, in order to average out slight irregularities in the heartbeat period and hence prevent some flickering of the displayed heartbeat data which may result from such irregularities. The circuits which perform processing of the output signal from photo-receptive element 20 will be referred to hereinafter and in the appended claims as the heartbeat signal processing circuits, and comprise amplifying and waveform shaping circuit 22, control signal generator circuit 24, counter circuit 26, memory circuit 28, and conversion circuit 30 in the embodiment of Fig. 1.

Fig. 2 shows an example of an arrangement of a heartbeat sensor for a heartbeat rate measurement system according to the prior art, with the heartbeat rate measurement system being incorporated in an electronic wristwatch. Numeral 34 denotes the heartbeat sensor, which comprises a photo-emissive element 36 and a photo-receptive element 20 disposed side by side, with the heartbeat sensor 34 being positioned below an aperture 44 in watch case 40, i.e. below a through-hole formed in watch case 40. Numeral 42 denotes a watch glass, and numeral 46 denotes a finger tip which is positioned at the outer end of through-hole 44 in order to sense changes in the shape of blood vessel 48 in finger tip 46 by means of heartbeat sensor 34. With such a heartbeat rate measurement system, the light which is produced by photo-emissive element 36 of heartbeat sensor 34 travels through through-hole 44 to finger tip 46, penetrates to blood vessel 48 in finger tip 46 and is reflected therefrom, and reflected light travels back through through-hole 44 to be incident upon photo-receptive element 20. In general, for reasons of practicability of manufacture, it will not be possible to position heartbeat sensor 34 on the exterior surface of the casing of a portable electronic device such as casing 40, so that through-hole heartbeat sensor cannot be set into direct contact with the portion of the body being utilized for heartbeat measurement. The light from photo-emissive element 36 must therefore travel through an aperture such as through-hole 44, communicating with the exterior of the casing 40, before reaching the finger tip 46, being reflected therefrom, and again travelling through through-hole 44 to reach photo-receptive element 20. In the case of a

portable electronic device such as an electronic wristwatch, the heartbeat sensor 34 must be extremely small, so that the photo-emissive area of photo-emissive element 36 and the photo-receptive area of photo-receptive element 20 will both be very small. Further, since the light emitted by photo-emissive element 36 must travel a substantial distance through casing 40 before being reflected from blood vessel 48 and then returning through through-hole 44, a considerable amount of this light will be lost by dispersion before being incident on photo-receptive element 20. As a result, the detection sensitivity of such a prior art arrangement for a heartbeat sensor of a heartbeat rate measurement system is very low, and operation will not be obtained unless the finger tip 46 is pressed into very close contact with the casing 40 of the electronic wristwatch. Even if this is done, the low detection sensitivity will present various technical problems, and this has made a practical implementation of such a heartbeat rate measurement system in a portable electronic device of very small size such as an electronic wristwatch extremely difficult.

Referring now to Fig. 3, an arrangement of a heartbeat sensor for a first embodiment of an heartbeat rate measurement system according to the present invention is shown, in partial cross-sectional diagram form. As in the case of the prior art example described above, the heartbeat rate measurement system of this embodiment is incorporated into an electronic wristwatch, and components which correspond to those shown in Fig 2 are denoted by identical reference numerals. Numeral 50 denotes an optical lens, which in this embodiment is a convex lens, and is positioned within through-hole 44 in watch case 40. With heartbeat sensor 34 being formed as an integral part of a watch module 38. Heartbeat sensor 34 comprises a photo-emissive element 36 and a photo-receptive element 20. The photo-emissive element 36 and photo-receptive element 20 are arranged in symmetrical opposition with respect to the optical axis L1 of optical lens 50, i.e. are positioned on opposite sides of optical axis L1, at equal distances therefrom. The upper surfaces of photo-emissive element 36 and photo-receptive element 20 are disposed in the same plane.

The heartbeat signal processing circuits and a display decoder/drive circuit for displaying the heartbeat rate, are also formed integrally in watch module 38, and can have the general configuration shown in Fig. 1 and described above, with signals from photo-receptive element 20 being input to an amplifying and pulse shaping circuit.

Light emitted by photo-emissive element 36 enters convex lens 50, is focussed thereby, and travels along a path indicated by broken line 37 to reach a focal point which is approximately in the neighbourhood of blood vessel 48 in finger tip 46. The reflected light from blood vessel 48 then re-enters convex lens 50 and is again directed and focussed thereby along a line indicated by broken line 39., to thereby become incident on photo-receptive element 20. As a result of the photo-emissive element 36 and photo-receptive element 20 being positioned in symmetrical opposition with respect to the optical axis L1 of convex lens 50, the reflected light from blood vessel 48 will be concentrated on the photo-receptive area of photo-receptive element 20, with a minimum amount of light being lost due to dispersion.

Thus, as a result of the focussing and directing action of convex lens 50 in reducing loss of light by dispersion, the detection sensitivity of an heartbeat rate measurement system utilizing the heartbeat sensor arrangement shown in Fig. 3 is much higher than that of a prior art arrangement such as that of Fig. 2. As a result of this enhanced detection sensitivity, the operation of a heartbeat rate measurement system according to the present invention can be made more accurate and reliable than has been possible in the past. In addition, due to the light from the photo-emissive element of the heartbeat sensor being focussed at a point exterior to the case of the portable electronic device incorporating the heartbeat rate measurement system, it is possible to perform accurate sensing of the heartbeat even if the user's body (e.g finger tip) is not pressed into close contact with the casing exterior, or is even slightly separated therefrom. Thus, such a system can be made much more convenient and accurate than has been possible in the prior art.

Referring now to Fig. 4, an arrangement of a heartbeat sensor according to another embodiment of the present invention is shown. As in the previous embodiment, the heartbeat rate measurement system is incorporated in an electronic wristwatch, having a case 41, and a watch glass 43, and the heartbeat sensor 34 is formed integrally in a watch module 40. This embodiment differs from that of Fig. 3 in that the convex lens, denoted by numeral 51, is provided within the watch glass 43, i.e. within a portion of watch glass 43 which is positioned immediately above the heartbeat sensor 34. The convex lens 51 can be either formed integrally in watch glass 43, by suitable shaping of a portion thereof, or can be formed as a separate component which is fitted into a through-hole provided in watch glass 43. The operation of convex lens 51 and the effects obtained thereby are as described for the embodiment Fig. 3.

Referring now to Fig. 5, another embodiment of a heartbeat sensor for a heartbeat rate measurement system according to the present invention is shown, with the system again being incorporated into an electronic wristwatch. In this embodiment, the heartbeat sensor 34 has the form shown in the oblique view of Fig. 6. The photo-emissive element 37 is positioned in the central portion of the heartbeat sensor, while the photo-receptive element 21 is formed in the shape of a ring which is positioned around the periphery of heartbeat sensor 34, concentric with the photo-emissive element 37. As indicated in Fig. 5, the optical axis L1 of convex lens 50, and the central axis S2 of heartbeat sensor 34 are arranged along

the same straight line, with heartbeat sensor 34 being positioned immediately below through-hole 34 in which convex lens 50 is retained. As indicated by the arrowed broken lines 45, light which is emitted by photo-emissive element 37 enters convex lens 50 and is focussed thereby, to a focal point which is close to blood vessel 48 in the finger tip 46. This light is then reflected from blood vessel 48 and again enters convex lens 50 to be converted thereby into a parallel light beam which travels back to be incident upon photo-receptive element 21 of heartbeat sensor 34. As in the previous embodiments, optical lens 50 serves to prevent loss of light by dispersion, as the light travels from photo-emissive element 37 and is reflected back from blood vessel 48 to reach photo-receptive element 21. In addition, with this embodiment, since photo-receptive element 21 is formed in the shape of a ring positioned around the periphery of photo-emissive element 37 in heartbeat sensor 34, the large photo-receptive area which can thereby be provided for photo-receptive element 21 serves to further substantially enhance the detection sensitivity of heartbeat sensor 34.

It is also possible to modify the embodiment shown in Fig. 5 such as to provide optical lens 50 as an integral part formed in watch glass 42 or as a separate component which is fitted into a through-hole in watch glass 42.

It should be noted that various modifications can be performed to the embodiments described above. For example, in the embodiment of Fig. 3, it is possible to form optical lens 50 to have different coefficients of refraction on opposite halves thereof, which are respectively positioned over photo-emissive element 36 and photo-receptive element 20 of heartbeat sensor 34, in which case it would not be necessary to dispose photo-emissive element 36 and photo-receptive element 20 positioned in symmetrical opposition with respect to the optical axis of optical lens 50. Similarly, it is possible to provide suitable optical means for directing the light out of and back to heartbeat sensor 34 such that it is not necessary to position heartbeat sensor 34 immediately below the optical lens.

It is also possible to use some type of lens other than the convex lens which is employed in the embodiments described above. Similarly, it is possible to arrange optical means for the embodiment of Fig. 5 whereby it is not necessary to arrange the central axis of the heartbeat sensor and the optical axis of the optical lens in the same straight line.

It should also be noted that the embodiment of Fig. 5 can be modified to position photo-receptive element 21 in the center of heartbeat sensor 34 and photo-emissive element 37 around the outer periphery thereof, concentric with photo-receptive element 21.

It can be understood from the above description that the present invention enables an heartbeat rate measurement system to be incorporated into a small size of portable electronic device such as an electronic wristwatch, in which the elements utilized to perform sensing of a heartbeat by responding to light reflected from blood vessels in the body must be of very small size, and that the present invention successfully overcomes the problem of unsatisfactory detection sensitivity which has arisen with such systems in the prior art. The present invention therefore makes the incorporation of such an heartbeat rate measurement system into an electronic wristwatch completely practical. Incorporation of such a system into an electronic wristwatch, which enables the user to immediately and automatically measure his or her heartbeat, would substantially enhance the market appeal of such an electronic wristwatch.

Although the present invention has been shown and described with reference to specific embodiments, the above description should be interpreted in a descriptive and not in a limiting sense. The scope claimed for the present invention is laid out in the appended claims.

CLAIMS

1. A portable electronic device provided with a heartbeat rate measurement system, comprising:

an outer case for containing said portable electronic device;

optical lens means mounted in said case for transferring light between the exterior and interior of said case;

a heartbeat sensor disposed inward of said optical lens means, said heartbeat sensor comprising a photo-emissive element and photo-receptive element, said photo-emissive element being positioned with respect to said optical lens means such as to transmit light emitted therefrom through said optical lens means to the exterior of said case, said optical lens means acting to focus said emitted light at a focal point external to said case, and said photo-receptive element being positioned with respect to said optical lens means such as to receive said emitted light after reflection thereof from a portion of a human body position external to said case, said optical lens means acting to direct and concentrate said reflected light on to said photo-receptive element, said photo-receptive element being responsive to variations in the level of said reflected light corresponding to a heartbeat of said human body for producing a heartbeat signal;

heartbeat signal processing circuit means for operating on said heartbeat signal to produce output signals indicative of the repetition rate of said heartbeat; and

display means responsive to said output signals from said heartbeat signal processing circuit means for displaying said heartbeat rate.

2. A portable electronic device provided with a heartbeat rate measurement system according to claim 1, in which said optical lens means comprise a convex lens.

3. A portable electronic device provided with a heartbeat rate measurement system according to

claim 1, in which said photo-receptive element and said photo-emissive element of said heartbeat sensor are disposed immediately adjacent to said optical lens means within said case.

4. A portable electronic device provided with a heartbeat rate measurement system according to claim 1, in which said photo-receptive element and said photo-emissive element of said heartbeat sensor are disposed in symmetrically opposite positions with respect to an optical axis of said optical lens means.

5. A portable electronic device provided with a heartbeat rate measurement system according to claim 1, in which one of said photo-receptive element and said photo-emissive element is positioned centrally in said heartbeat sensor and the other one thereof is formed in said heartbeat sensor surrounding the periphery of said centrally positioned element and concentric therewith.

6. A portable electronic device provided with a heartbeat rate measurement system according to claim 5, in which a central axis of said heartbeat sensor and an optical axis of said optical lens means are arranged in a common straight line.

7. A portable electronic device provided with a heartbeat rate measurement system according to claim 1, in which said portable electronic device is an electronic wristwatch.

8. A portable electronic device provided with a heartbeat rate measurement system according to claim 6, in which circuits of said electronic wristwatch are formed integrally in a watch module, and in which said heartbeat sensor is mounted in said watch module as an integral part thereof.

9. A portable electronic device provided with a heartbeat rate measurement system, substantially as hereinbefore described with reference to figures 1 and 2 to 6 of the accompanying drawings.

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